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THE EFFECT OF MICROSTRUCTURE ON THE PROPERTIES

OF HIGH STRENGTH ALUMINUM ALLOYS

Final Report on

AFOSR-78-3471

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by

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Abstract

This program was initiated in January, 1978, and was concerned with the effect of microstructure on the properties of two different classes of aluminum alloys of current interest to the Air Force: (1) high strength Aℓ-Zn-Mg-X alloys and (2) low density, high modulus Aℓ-Li-X alloys. The program terminated on December 31, 1982. Work prior to 1982 has been described in detail in our Annual Scientific Reports, the last of which was issued in February, 1982. This Final Report will list publications resulting from work on AFOSR Grant No. 78-3471 and summarize results obtained in 1982.

1. The Microstructure and Properties of An Extruded P/M X7091 Plate (Walker and Starke)

Rapid solidification and powder metallurgy (P/M) consolidation offers a means of producing finer dendrite cells, finer dispersions of intermetallic compounds, fewer undissolved constituents and fewer innomogeneities when compared with I/M methods. Early feasibility studies on combining age and dispersion hardening alloy additions in 7XXX alloys led to the development of a P/M consolidation process for fabricating high quality, blister free products. Although high axial tensile strength and good stress corrosion cracking resistance were produced, the products were plagued by low fracture toughness, especially in the short transverse direction. Since then, modifications to early fabrication processes have greatly improved fracture toughness and have allowed the production of 7XXX alloys with equal or superior combinations of strength, toughness and SCC resistance when compared with equivalent I/M alloys. To date, the quantitative evaluation of P/M microstructures and the relationship of these microstructures to cyclic stress and strain has been limited.

The purpose of this study was to characterize the microstructure of an extruded PM X7091 plate and to evaluate the alloy's monotonic and cyclic properties. The results were compared with 7XXX I/M alloys. Better combinations of tensile properties were obtained by rapid solidification and P/M consolidation methods. However, anticipated improvement in fatigue crack initiation resistance was not realized due to the presence of oxides along grain boundaries. In order to obtain better fatigue properties, processing procedures that dissociate the boundaries from the oxides should be utilized. A manuscript resulting from this research has been submitted to Powder Metallurgy.

2. The Influence of Grain Structure on the Ductility of the Aℓ-Cu-Li-Mn-Cd Alloy 2020 (Starke and Lin)

The main purpose of adding lithium to aluminum alloys is to obtain a better combination of low density, high elastic modulus, and high strength; properties especially attractive for aerospace applications. The first commercial lithium-containing aluminum alloy was made available by Alcoa in 1958, and designated 2020 by the Aluminum Association. Although 2020 had a room temperature strength comparable to 7075-T6 and an elevated temperature stability higher than other age hardenable aluminum alloys, its low ductility and fracture toughness in the maximum strength temper led to the termination of production in 1969.

The purpose of this research was to study the influence of grain structures, as produced by various TMT's, on the ductility of 2020 plate. Materials having a completely or partially recrystallized structure exhibited elongation between 4 and 8% when aged to peak strength. For both cases the low ductility was associated with (a) planar deformation, (b) random texture, (c) the presence of large intermetallic compounds along the recrystallized grain boundaries, and (d) precipitate-free zones. The first three enhance crack nucleation at high angle grain boundaries, and subsequent crack propagation occurs along the precipitate-free zones. The completely unrecrystallized materials had elongation between 10 and 13% in both longitudinal and transverse directions. The high ductility was associated with a sharp texture and a transgranular fracture mode. The maximum ductility was obtained by reducing the unrecrystallized grain size. The results of this study suggest that improved properties of a 2020-type alloy may be obtained by lowering the Fe and Si contents to remove coarse constituent phases, eliminating Cd, and replacing Mn with Zr in order to obtain a highly texture, unrecrystallized structure. The results of this program were published in <u>Metallurgical Transactions</u>

Vol. 13A, December, 1982, pp. 2259-2269.

3. Effects of Precipitation Heat Treatment on the Microstructure, Toughness, and Stress Corrosion Crack Propagation Resistance of Aluminum Alloy 2020 (Rinker and Sanders)

The objective of this research was to determine the effects of precipitation heat treatment on the strength, toughness, microstructure, and stress corrosion resistance of 2020. The peak strength temper and several underaged and overaged conditions were studied. Precipitation strengthening was found to be due to extensive co-precipitation of the $\theta'(A\ell_2Cu)$ and $T_1(A\ell_2CuLi)$ phases, confirming the results of previous studies. Although some evidence of δ' precipitation was also found, no significant contribution to strengthening was attributed to this phase.

Fracture toughness was found to decrease markedly with aging to peak strength due to an increasing tendency toward strain localization by the concentration of deformation into intense planar bands and the concomitant decrease in strain hardening capacity. The strength/toughness relationship for several high strength underaged tempers of 2020 was found to be superior to that for the peak strength temper and for standard tempers of other 2XXX alloys. One underaged temper with a yield strength 12% lower than the peak aged temper had 80% higher plane strain fracture toughness and 300% higher crack propagation resistance. The toughness of overaged tempers was found to be to be much lower than that of underaged tempers having the same yield strength.

The stress corrosion cracking resistance of 2020 in the peak strength temper and several high strength underaged tempers was found to be excellent. Poor SCC resistance was observed for a very underaged temper. A model was developed which associates SCC resistance with the electrochemical potential

difference between grain boundary T_1 precipitates and the interior of grains.

A manuscript is being prepared for submission to Metallurgical Transactions.

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DEGREES GRANTED UNDER AFOSR-78-3471

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This program was initiated in January, 1978, and was concerned with the effect of microstructure on the properties of two different classes of aluminum alloys of current interest to the Air Force: (1) high strength Al-Zn-Mg-X alloys and (2) low density, high modulus Al-Li-X alloys. The program terminated on December 31, 1982. Work prior to 1982 has been described in detail in our Annual Scientific Reports, the last of which was issued in February, 1982. This Final Report will list publications resulting from work on

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AFOSR Grant No. 78-3471 and summarize results obtained in 1982.

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